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# REPORT FOR CONSULTATION ON THE PUGET SOUND AIR QUALITY CONTROL REGION (WASHINGTON).

National Air Pollution Control Administration
Washington, D.C.

July 1969

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# REPORT FOR CONSULTATION ON THE

# PUGET SOUND

# AIR QUALITY CONTROL REGION

# (WASHINGTON)

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Consumer Protection and Environmental Health Service
National Air Pollution Control Administration

July 1969

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NATIONAL TECHNICAL
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U S Department of Commerce
Springfield VA 22151

TABLE OF CONTENTS


| | Page |
|---|---|
| Preface | 3 |
| Introduction | 4 |
| Evaluation of Urban Factors | 12 |
| Summary | 24 |
| Evaluation of Engineering Factors | 27 |
| Summary | 49 |
| Proposal | 51 |
| Discussion of Proposal | 51 |
| References | 56 |

## PREFACE

The Secretary, Department of Health, Education, and Welfare, is directed by the Air Quality Act of 1967 to designate "air quality control regions" as an initial step toward the establishment of regional air quality management. In addition to listing the major factors to be considered in the development of region boundaries, the Act stipulates that the designation of a region shall be preceded by consultation with appropriate State and local authorities.

The National Air Pollution Control Administration, DHEW, has conducted a study of the Puget Sound area, the results of which are presented in this report. The Region* boundaries proposed in this report reflect consideration of all available and pertinent data; however, the boundaries remain subject to revisions suggested during consultation with State and local authorities. Formal designation of a Region will follow the consultation meeting. This report is intended to serve as background material for the consultation.

The Administration appreciates assistance received either directly during the course of this study or indirectly during previous activities in the Puget Sound area from official air pollution control agencies at the State and local level, and the Puget Sound Governmental Conference.

*For the purposes of this report, the word region, when capitalized, will refer to the Puget Sound Air Quality Control Region. When not capitalized, unless otherwise noted, it will refer to air quality control regions in general.

# INTRODUCTION

"For the purpose of establishing ambient air quality standards pursuant to section 108, and for administrative and other purposes, the Secretary, after consultation with appropriate State and local authorities shall, to the extent feasible, within 18 months after the date of enactment of the Air Quality Act of 1967 designate air quality control regions based on jurisdictional boundaries, urban-industrial concentrations, and other factors including atmospheric areas necessary to provide adequate implementation of air quality standards. The Secretary may from time to time thereafter, as he determines necessary to protect the public health and welfare and after consultation with appropriate State and local authorities, revise the designation of such regions and designate additional air quality control regions. The Secretary shall immediately notify the Governor or Governors of the affected State or States of such designation."

Section 107(a)(2), Air Quality Act of 1967

## THE AIR QUALITY ACT

Air pollution in most of the Nation's urban areas is a regional problem. This regional problem demands a regional solution, consisting of coordinated planning, data gathering, standard setting, and enforcement. Yet, with few exceptions, such coordinated efforts are notably absent among the Nation's urban complexes.

Beginning with the Section quoted above, in which the Secretary is required to designate air quality control regions, the Air Quality Act presents an approach to air pollution control involving coordinated efforts by Federal, State, and local governments, as shown in Figure 1. After the Secretary has (1) designated regions, (2) published air quality criteria, and (3) published corresponding documents on control technology and associated costs, the Governor(s) of the State(s) must file with the Secretary within 90 days a letter of intent, indicating that the State(s) will adopt within 180 days ambient air quality standards for the pollutants

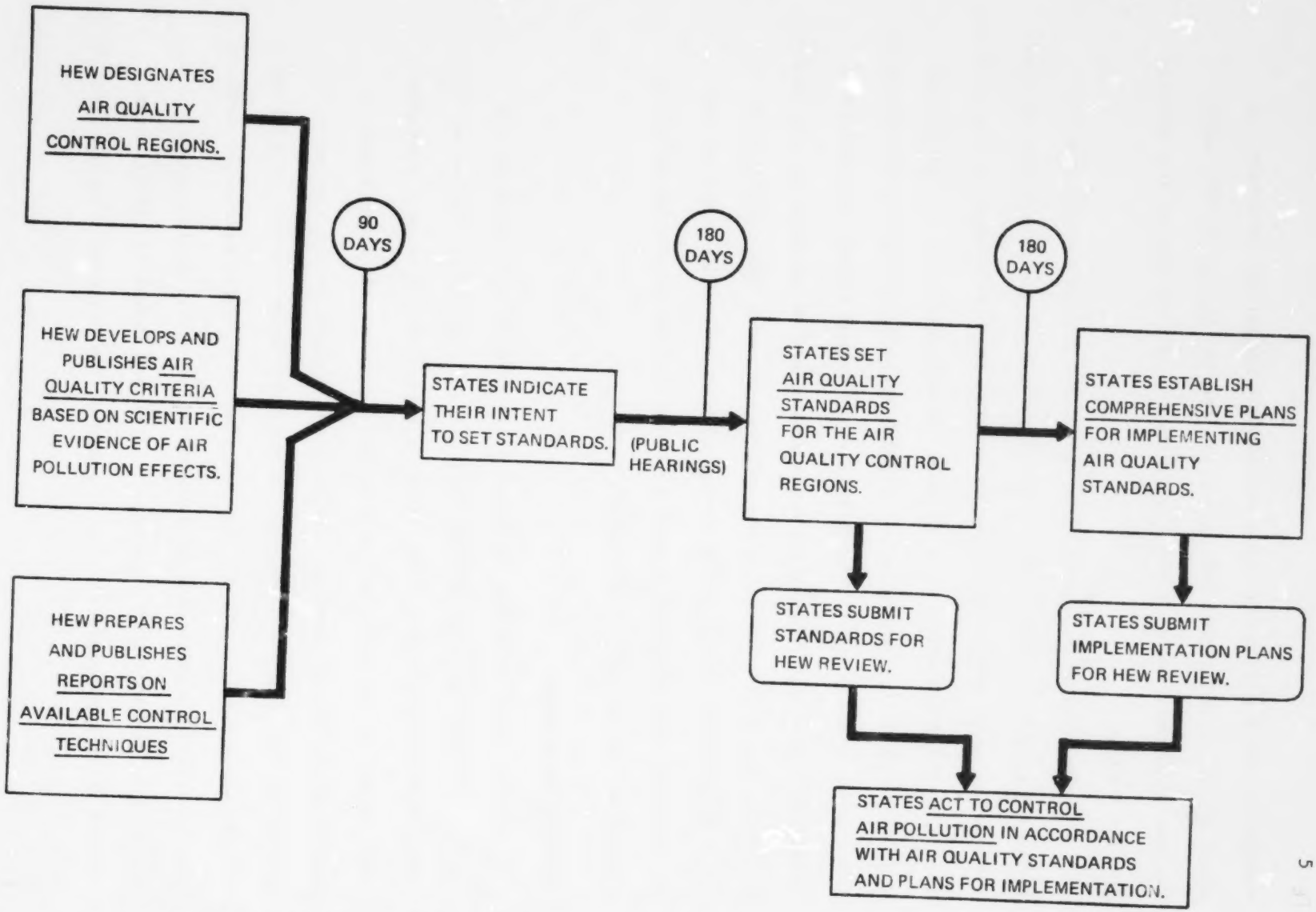

HEW DESIGNATES AIR QUALITY CONTROL REGIONS.
HEW DEVELOPS AND PUBLISHES AIR QUALITY CRITERIA BASED ON SCIENTIFIC EVIDENCE OF AIR POLLUTION EFFECTS.
HEW PREPARES AND PUBLISHES REPORTS ON AVAILABLE CONTROL TECHNIQUES
90 DAYS
STATES INDICATE THEIR INTENT TO SET STANDARDS.
180 DAYS
(PUBLIC HEARINGS)
STATES SET AIR QUALITY STANDARDS FOR THE AIR QUALITY CONTROL REGIONS.
180 DAYS
STATES ESTABLISH COMPREHENSIVE PLANS FOR IMPLEMENTING AIR QUALITY STANDARDS.
STATES SUBMIT STANDARDS FOR HEW REVIEW.
STATES SUBMIT IMPLEMENTATION PLANS FOR HEW REVIEW.
STATES ACT TO CONTROL AIR POLLUTION IN ACCORDANCE WITH AIR QUALITY STANDARDS AND PLANS FOR IMPLEMENTATION.

**Figure 1** FLOW DIAGRAM FOR ACTION TO CONTROL AIR POLLUTION ON A REGIONAL BASIS, UNDER THE AIR QUALITY ACT.

covered by the published criteria and control technology documents and adopt within an additional 180 days plans for the implementation, maintenance, and enforcement of those standards in the designated air quality control regions.

The new Federal legislation provides for a regional attack on air pollution and, at the same time, allows latitude in the form which regional efforts may take. While the Secretary retains approval authority, the State(s) involved in a designated region assumes the responsibility for developing standards and an implementation plan which includes administrative procedures for abatement and control. For regions which extend across jurisdictional boundaries, informal cooperative arrangements may be adequate in some cases to insure compatible standards and enforcement among the jurisdictions. In other cases, more formal arrangements, such as interstate compacts, may be selected. The objective in each instance will be to provide effective mechanisms for control on a regional basis.

## THE SIZE OF A REGION

Several objectives are important in determining how large an air quality control region should be. Basically, these objectives can be divided into three separate categories. First, a region should be self-contained with respect to air pollution sources and receptors. In other words, a region should include most of the important sources in the area as well as most of the people and property affected by those sources. In this way, all the major elements of the regional problem will lie within one unified administrative jurisdiction. Unfortunately, since air pollutants can travel long distances, it is impractical if not impossible to delineate regions which are completely self-contained. The air over a region will

usually have at least trace amounts of pollutants from external sources. During episodic conditions, such contributions from external sources may even reach significant levels. Conversely, air pollution generated within a region and transported out of it can affect external receptors to some degree. It would be impractical and inefficient to make all air quality control regions large enough to encompass these low-level trace effects. The geographic extent of trace effects overestimates the true problem area which should be the focus of air pollution control efforts. Thus, the first objective, that a region be self-contained, becomes a question of relative magnitude and frequency. The dividing line between "important influence" and "trace effect" will be a matter of judgment. The judgment should be based on estimates of the impact a source has upon a region, and the level of pollution to which receptors are subjected. In this respect, annual and seasonal data on pollutant emissions and ambient air concentrations are a better measure of relative influence than short term data on episodic conditions.

The second general objective requires that region boundaries be designed to meet not only present conditions but also future conditions. In other words, the region should include areas where industrial and residential expansion are likely to create air pollution problems in the foreseeable future. This objective requires careful consideration of existing metropolitan development plans, expected population growth, and projected industrial expansion. Such considerations should result in the designation of regions which will contain the sources and receptors of regional air pollution for a number of years to come. Of course, region boundaries need not be permanently fixed, once designated. Boundaries

should be reviewed periodically and altered when changing conditions warrant readjustment.

The third objective is that region boundaries should be compatible with and even foster unified and cooperative governmental administration of the air resource throughout the region. Air pollution is a regional problem which often extends across several municipal, county, and even state boundaries. Clearly, the collaboration of several governmental jurisdictions is prerequisite to the solution of the problem. Therefore, the region should be delineated in a way which encourages regional cooperation among the various governmental bodies involved in air pollution control. In this regard, the existing pattern of governmental cooperation on the whole range of urban problems may become an important consideration. Certainly the pattern of cooperation among existing air pollution control programs is a relevant factor. In general, administrative considerations dictate that governmental jurisdictions should not be divided. Although it would be impractical to preserve State jurisdictions undivided, usually it is possible to preserve the unity of county governments by including or excluding them in their entirety. Occasionally, even this would be impractical due to a county's large size, wide variation in level of development, or striking topographical features.

To the extent that any two of the above three objectives lead to incompatible conclusions concerning region boundaries, the region must represent a reasonable compromise. A region should represent the best way of satisfying the three objectives simultaneously.

PROCEDURE FOR DESIGNATION OF REGIONS

Figure 2 illustrates the procedures used by the National Air Pollution Control Administration for designating air quality control regions.

A preliminary delineation of the region is developed by bringing together two essentially separate studies -- the "Evaluation of Engineering Factors," and the "Evaluation of Urban Factors."

The study of "Engineering Factors" indicates the location of pollution sources and the geographic extent of serious pollutant concentrations in the ambient air. Pollution sources are located by taking an inventory of emissions from automobiles, industrial activities, space heating, waste disposal, and other pollution generators. The distribution of pollutants in the ambient air is analyzed on the basis of measured air quality data, the location of emissions, and meteorological information. As a whole, the engineering study indicates how large the air quality control region must be in order to encompass most pollution sources and most people and property affected by those sources.

The study of "Urban Factors" encompasses nonengineering considerations. It reviews existing governmental jurisdictions, current air pollution control programs, present concentrations of population and industry, and expected patterns of urban growth. Other nonengineering factors are discussed when they are relevant. As a whole, the study of urban factors indicates how large an air quality control region must be in order to encompass expected growth of the pollution problem in the

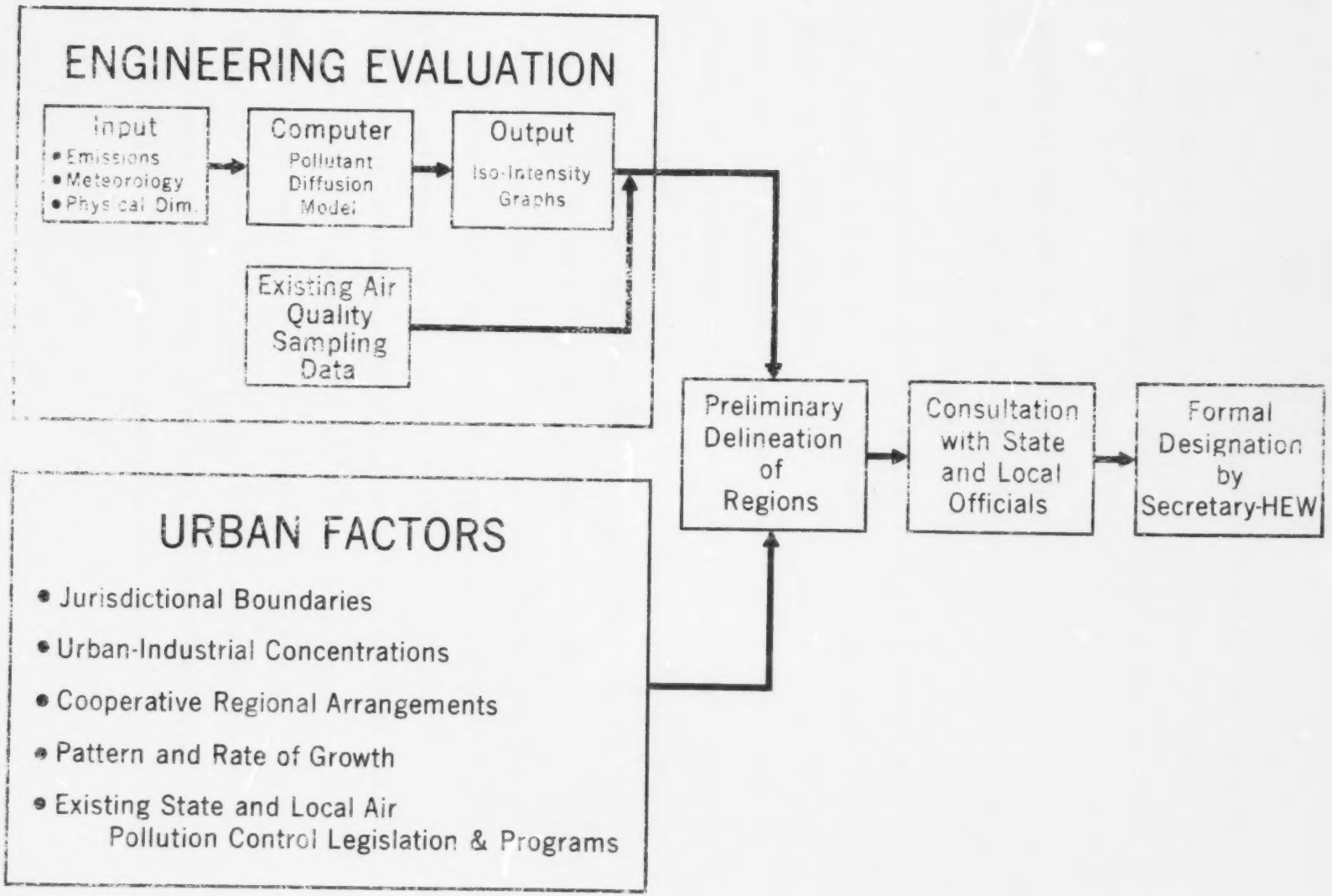



Figure 2. Flow diagram for the designation of air quality control regions.

future. It also considers which group of governmental jurisdictions will most effectively administer a strong regional air quality control program.

The conclusions of the engineering study are combined with the results of the urban factors study to form the basis of an initial proposal for an air quality control region. As shown in Figure 2, the proposal is then submitted for consultation with State and local officials. After reviewing the suggestions raised during the consultation, the Secretary formally designates the region with a notice in the Federal Register and notifies the governors of the States affected by the designation.

The body of this report contains a proposal for the boundaries of the Puget Sound Air Quality Control Region and supporting studies on engineering and urban factors. The report itself is intended to serve as the background document for the formal consultation with appropriate State and local authorities.

# EVALUATION OF URBAN FACTORS

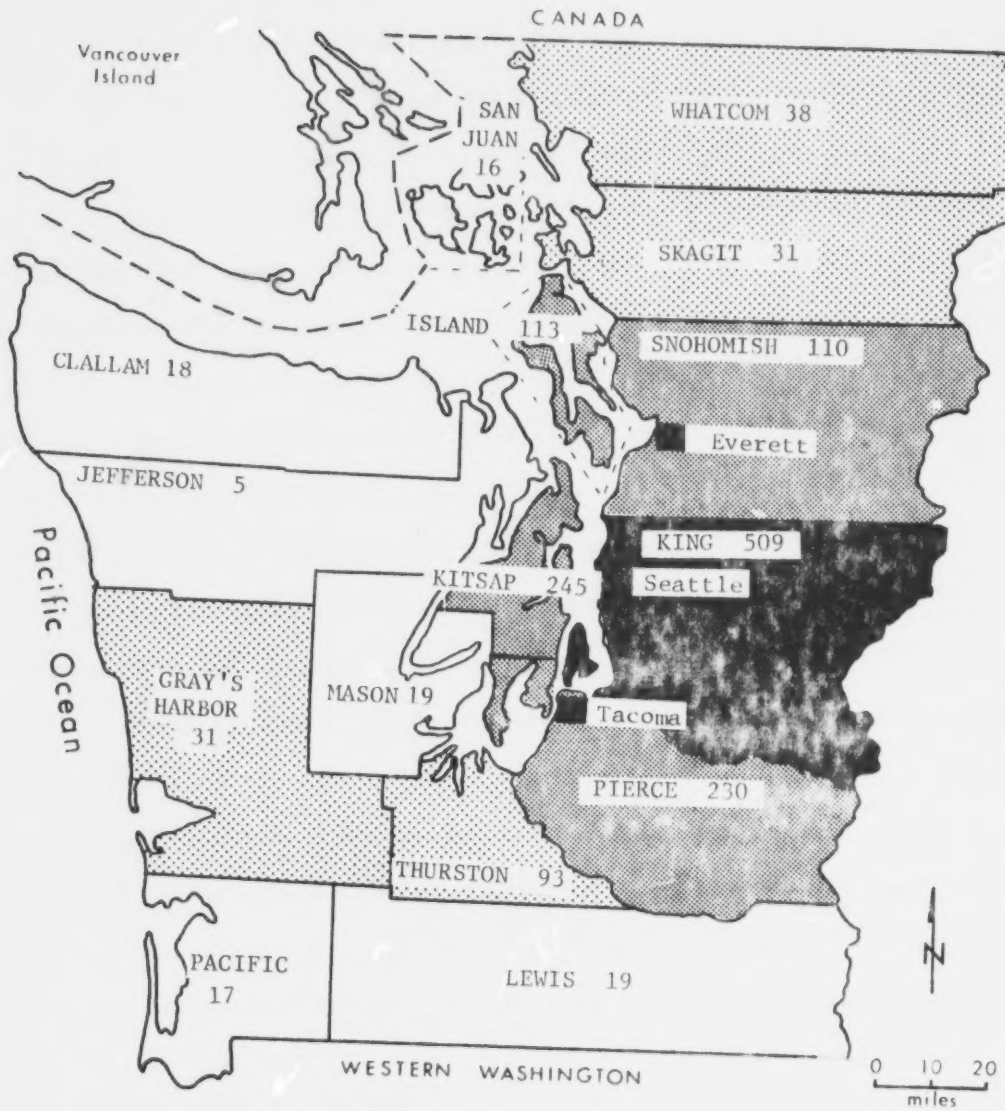
## INTRODUCTION

A number of urban factors are relevant to the problem of defining air quality control region boundaries. First, the location of population is an important consideration, since human activity is the primary cause of air pollution, and humans are the ultimate victims. The projected population growth pattern is another important consideration, since an air quality control region should be designed not only for the present but also for the future. The location of industrial activity and the industrial growth pattern are relevant considerations for similar reasons. Political and jurisdictional considerations are important, since the Air Quality Act of 1967 envisions regional air pollution programs based on cooperative efforts among many political jurisdictions. The following discussion of urban factors will present these considerations as they apply to the Puget Sound area.

## POPULATION

Figure 3 displays present population densities in the Puget Sound area (1). The counties in the area can be divided into three categories according to population density. The category with the highest population density (over 500 residents per square mile) contains only King County. The category with moderate population densities (from 100 to 500 residents per square mile) contains four counties: Pierce, Kitsap, Snohomish, and Island. Together these five counties contain more than 85% of the total population of the twelve counties adjacent to the

Figure 3:




1968 POPULATION DENSITY
Residents Per Square Mile

- more than 500;
- 100 to 500;
- 20 to 100;
- less than 20;

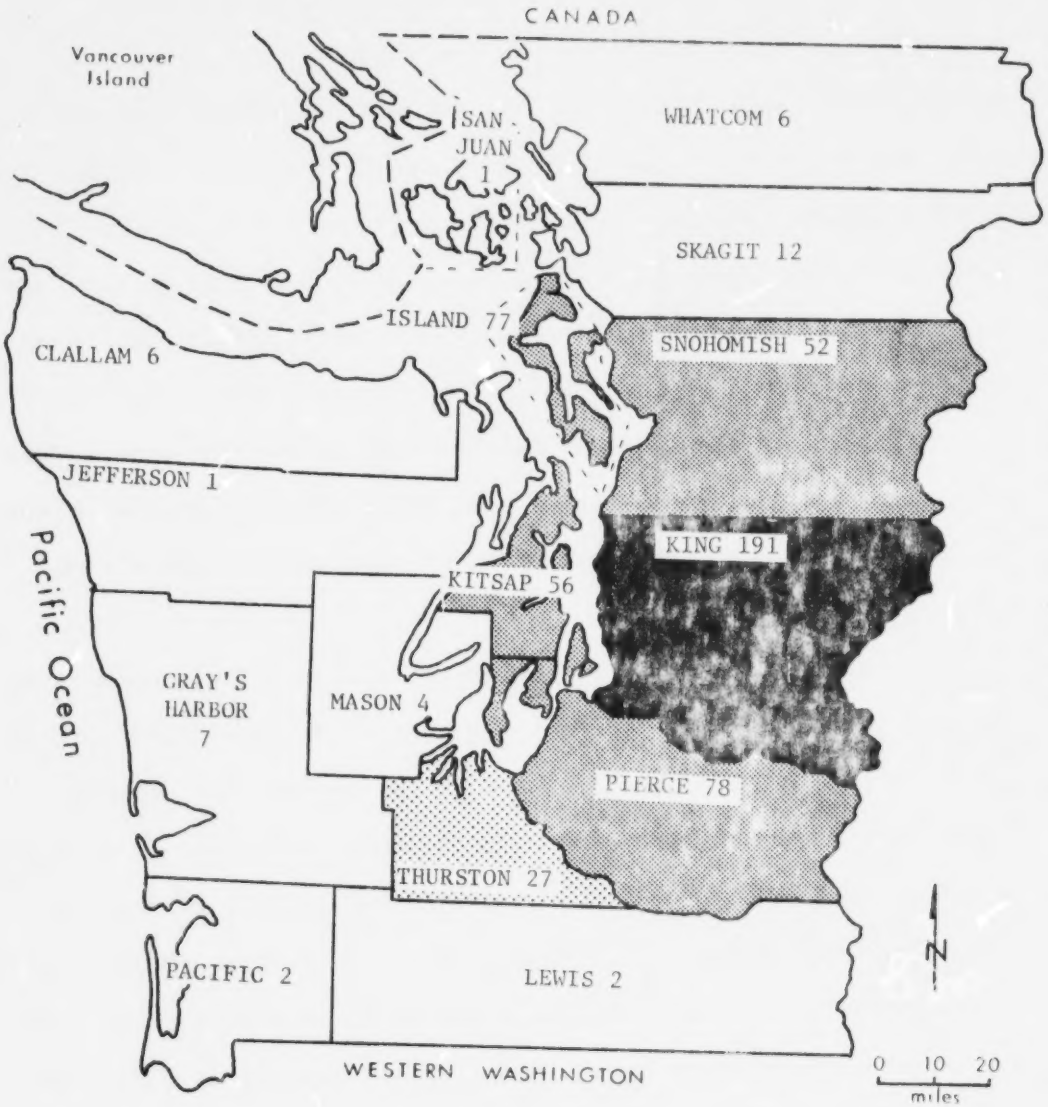
Puget Sound. In fact, three of these counties alone, King, Pierce, and Snohomish, contain nearly 80% of the total population. In turn, nearly 50% of the population of these last three counties resides within the three largest cities in the Puget Sound area; Seattle, Tacoma, and Everett. Each of these cities lies adjacent to the Sound in a basin formed by the Olympic Mountains on the west and the Cascade Range on the east. Most of the population in King, Pierce, and Snohomish Counties outside of the three cities resides in suburban communities which are located along the corridor of land which connects the three cities. In other words, King, Pierce, and Snohomish are heavily populated along the corridor, but sparsely populated elsewhere. Thus, the population densities calculated on a county-wide basis and presented in Figure 3 are averages which underestimate the actual population densities along the corridor. On the other hand, population in Kitsap and Island Counties is more evenly distributed, so that the average densities presented in Figure 3 more accurately indicate the actual population density of those portions of Kitsap and Island Counties which are involved in the Puget Sound area. Therefore, it is misleading to include Kitsap and Island Counties in the same population density category as Pierce and Snohomish, since the corridor portions of Pierce and Snohomish are much more densely developed than counterpart areas in Kitsap and Island.

The group of counties with the lowest population densities (less than 100 residents per square mile) contains all of the counties surrounding the five mentioned above. Within this group, the county which has the highest population density is Thurston, which contains the State Capitol, Olympia.

A number of organizations have projected population growth by county in the Puget Sound area. For the purposes of this report, the projections published during 1966 by the Department of Commerce and Economic Development of the State of Washington are the most useful since they cover all of the counties in the study area (2). Figure 4 displays population growth expected to take place during the next 16 years, according to the State projections. King County is expected to experience the largest absolute population growth, with 191 additional residents per square mile by 1985. Pierce, Island, Kitsap, and Snohomish follow, with 50 to 80 additional residents per square mile anticipated. Surrounding counties are likely to register little or no growth, except for Thurston, which is projected to have 27 additional residents per square mile by 1985.

In sum, on the basis of population estimates and projections, the corridor of land along the eastern shoreline of the Puget Sound constitutes the core of the urbanized area. At the present time, Seattle, Tacoma, and Everett are the three focal points of urbanization along this corridor. The bulk of population growth during the next 16 years is expected to spread along the corridor between these three cities. However, there will be some tendency for population growth to extend into the western side of Puget Sound. The proposed development of regional transportation facilities will accelerate the spread of population north and south along the eastern side of the Sound and to communities on the western side of the Sound. Areas not adjacent to the Sound are expected to register little or no growth during the near future.

Figure 4:




POPULATION GROWTH, 1968 - 1985

Additional Residents Per Square Mile:

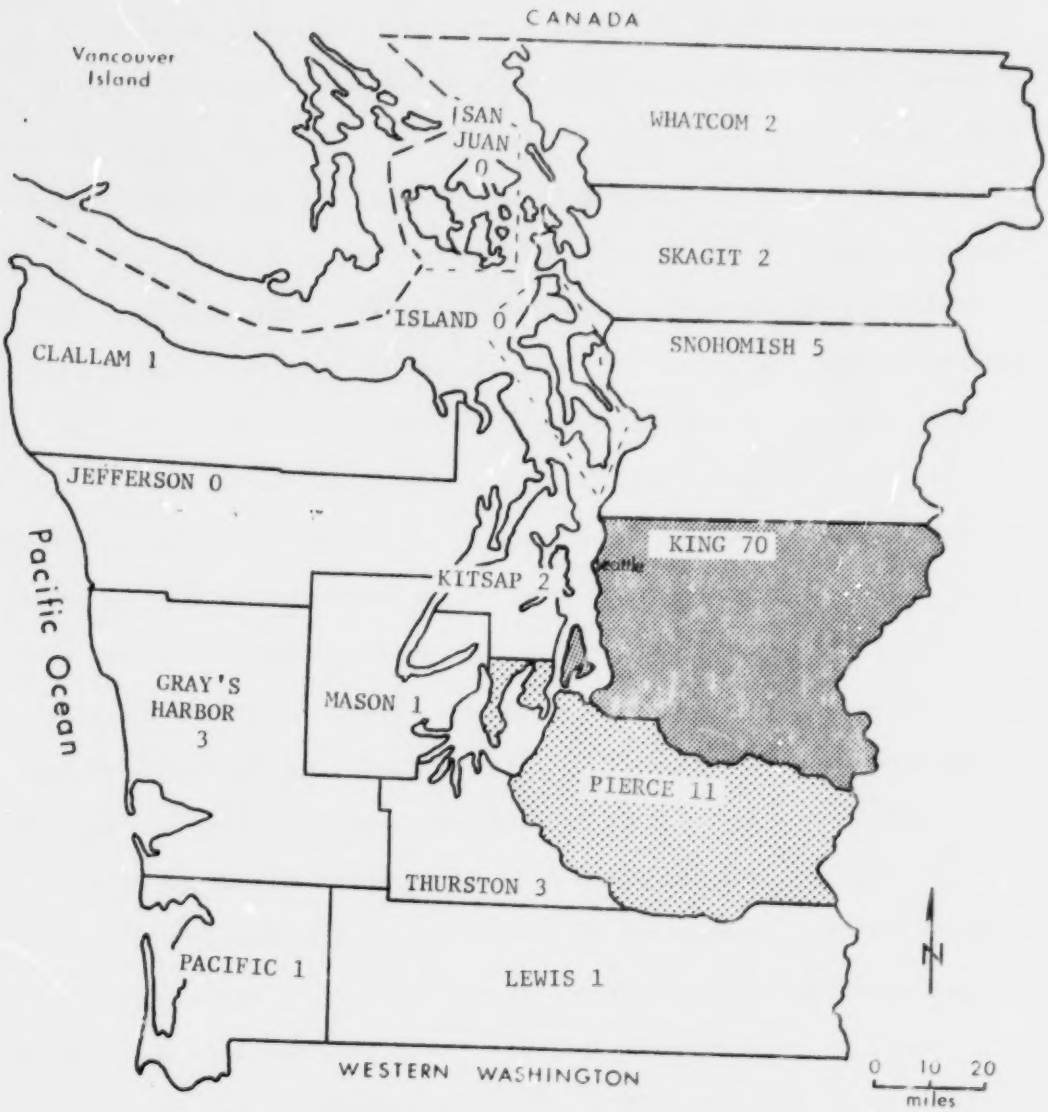
- more than 100;
- 50 to 100;
- 25 to 50;
- less than 25;

INDUSTRY

One method for determining the location of manufacturing activity is based on the number of people employed in manufacturing firms. As shown in Figure 5, which is based on 1967 data (3), King County has by far the highest density of people employed in manufacturing firms. Pierce County follows with a moderate density of manufacturing activity, and surrounding counties have little or no activity. Employment statistics (4) reveal that nearly two-thirds of the people employed by manufacturing firms in King County work in the aerospace industry. Fabricated metal products, machinery, and ship building account for another 10% of the manufacturing employment in King County. In Pierce County nearly 25% of the manufacturing employment is involved in lumber and wood products and about 16% in food products. In Snohomish County nearly 50% of the manufacturing employment is involved in lumber, wood, and paper products. In 1967, somewhat less than 20% of the manufacturing employment worked on aircraft products, but this type of employment has increased significantly during the last two years due to the recent completion of a new aircraft factory. Kitsap and Island Counties are primarily residential and recreational, except for the shipyard activity in Kitsap.

Growth of employment in the Puget Sound area has been anticipated in the land use plan for 1990 which was recommended by the Puget Sound Regional Transportation Study. Most of the employment growth is expected to occur along the corridor connecting Seattle, Tacoma, and Everett on the eastern side of Puget Sound. Only limited industrial development in Kitsap and Island Counties is expected.

Figure 5:




MANUFACTURING EMPLOYMENT DENSITY, 1967

Employees Per Square Mile:

more than 50;
10 to 50;
less than 10;

## EXISTING AIR POLLUTION CONTROL PROGRAMS

The Washington Clean Air Act of 1967 established, within the State Department of Health, an Air Pollution Control Board which is composed of nine members appointed by the Governor. Among the duties assigned to the Board by the 1967 Act were the responsibilities to adopt and enforce air quality goals and emission regulations, to monitor air quality, and to give technical assistance to local programs within the State. Amendments to the law enacted during 1969 expanded and further defined the duties of the Board. It was given the authority to adopt air quality objectives (levels of contaminants in the air below which undesirable effects will not occur), air quality standards (levels of air pollution which shall not be exceeded), and emission standards (limitations on the release of contaminants into the ambient air). The State Board was assigned responsibility for enforcement of its standards except in areas where local programs are enforcing standards which are at least as stringent as those of the State. However, the State was directed to exercise statewide control over emissions from certain categories of pollution sources if such control was determined to be in the public interest and for the protection of the welfare of the citizens.

One primary function of the State program has been to foster the development of county and multicounty programs throughout the State. To serve this end, the State program may assist the various local programs with financial aid. The present annual budget of the State program is slightly more than one million dollars.

The 1967 Washington Clean Air Act declared as public policy that "regional air pollution control programs are to be encouraged and supported to the extent practicable as essential instruments for the securing and maintenance of appropriate levels of air quality." In order to facilitate this policy, the Act created in each county an air pollution control authority. For certain classes of counties, the air pollution control authorities were declared "activated;" in others, the authorities were declared "inactive." The Act provided, however, that a county may change its status from "inactive" to "activated" on its own initiative. The 1967 Act further required certain contiguous counties to join in establishing one multi-county authority rather than several separate county authorities. Counties which were not required to join multi-county authorities nevertheless were allowed to do so on their own initiative if they desired. In addition, the 1967 Act defined several regional air pollution control authorities, composed of various multi-county and single-county authorities. Regional authorities were not required to become "activated" until July 1, 1969, and even then only regional authorities with at least one million population were required to become "activated." However, regional authorities were allowed to become activated on their own initiative prior to the required deadline provided the member counties so desired. In general, a multi-county authority superseded county authorities, and a regional authority superseded both multi-county and county authorities. Each type of authority was granted the power to adopt resolutions and issue orders to control air pollution. Furthermore, they could hold hearings, prepare comprehensive plans, require registration and reporting of air pollution sources, require notice

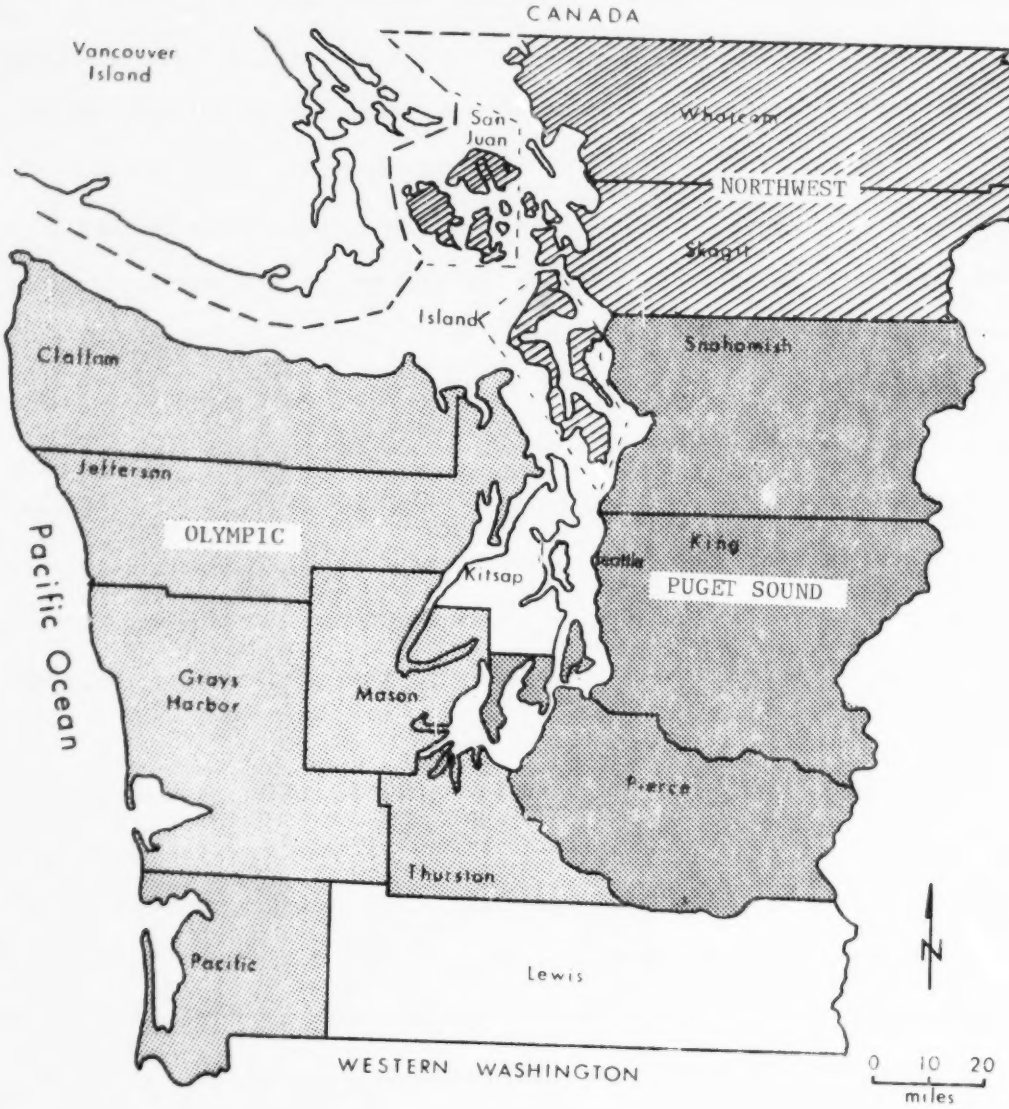
of construction of facilities which might be air contaminant sources, issue stop-construction orders, and grant variances.

Between 1967 and 1969 three multi-county authorities were established in the general Puget Sound area under the provisions of the 1967 Washington Clean Air Act (see Figure 6). The Puget Sound Air Pollution Control Agency was created with jurisdiction over King, Pierce, and Snohomish Counties. The Northwest Air Polution Control Agency contains Whatcom, Skagit, San Juan, and Island Counties. The Olympic Air Pollution Control Agency contains Clallam, Jefferson, Mason, Grays Harbor, Thurston, and Pacific Counties. Kitsap County, in the center of the Puget Sound area, did not activate its county authority or join any of these multi-county authorities. Of these three multi-county authorities, only the Puget Sound Agnecy was required by the 1967 Act to become activated. The other two multi-county authorities were established at the initiative of the member counties.

As defined in the 1967 Act, the Regional Air Pollution Control Authority for the Puget Sound area contained all twelve counties which have a border on the Puget Sound and Juan de Fuca Strait: Whatcom, Skagit, Snohomish, King, Pierce, Thurston, Kitsap, Mason, Jefferson, Clallam, Island, and San Juan Counties. Since together these counties contained more than one million residents, they were required to establish a regional authority by July 1, 1969. However, before that deadline became due, the Washington State Legislature amended the 1969 Act by deleting all requirements for the activation of regional authorities. Therefore, the Puget Sound Regional Authority has not been created.

Figure 6:

AIR POLLUTION CONTROL AUTHORITIES



The 1969 amendments to the 1967 Act created "air pollution control districts." The Puget Sound air pollution control district was defined to include fourteen counties - the twelve counties formerly in the Puget Sound Regional Authority plus Grays Harbor and Pacific Counties. Thus, the Puget Sound air pollution control district includes all of the counties presently in the Puget Sound, Northwest, and Olympic multi-county air pollution control authorities as well as Kitsap County, which has not yet joined any of these authorities. The 1969 amendments require the State Board to establish a district office in the Puget Sound district. The district office will be responsible for assisting the multi-county authorities in abating air pollution, aiding the State Board in establishing air quality standards and minimum emission standards for the district, insuring the enforcement of such standards, and carrying out other functions.

The Puget Sound Air Pollution Control Agency is a multi-county authority created during July, 1967, under the provisions of the Washington Clean Air Act. Its jurisdiction includes three counties; King, Pierce, and Snohomish. Thus, it encompasses the cities of Seattle, Tacoma, and Everett. In exercising the powers granted to it by State law, the Puget Sound Agency has adopted emission standards which control some types of outdoor burning and prohibit certain levels of particulate and sulfur oxide emissions. The Agency requires registration of most emission sources and notice of construction for potential new emission sources. A monitoring system has been established in the three-county area to measure air quality. The present annual budget of the Puget Sound Agency is about 730 thousand dollars.

REGIONAL COORDINATION AND PLANNING THE THE PUGET SOUND AREA

The only multi-county planning agency in the Puget Sound area is the Puget Sound Governmental Conference, which is composed of members from four counties; King, Pierce, Snohomish, and Kitsap. The Conference was created during 1957 in response to a growing need for regional coordination and planning. During its twelve years in existence, the Governmental Conference has adopted an open space plan, a street and highway plan, a regional transit plan, and a metropolitan area public transportation plan. These various plans form elements of a comprehensive plan for the development of the four-county region. Recently the Conference developed a work program for the next five years. The work program contains activities in eight major component area: economic and demographic study, regional social environment, regional physical environment, regional transportation planning, regional urban form and land use, program and policy communication and coordination, regional information systems, and special studies. Under the component "regional physical environment", the Conference expects to deal with water policy coordination, air policy coordination, solid waste disposal systems, water and sever systems, and open space conservation. The Conference has been expanding its manpower and budget to meet this ambitious expansion of program activities. The Conference budget for 1969 is larger than one million dollars.

SUMMARY

The evaluation of urban factors has shown that about 80% of the population in the Puget Sound area resides in three counties; King, Pierce, and Snohomish. Furthermore, the major portion of expected population

growth during the next sixteen years will probably be located in these three counties. Two additional counties, Kitsap and Island, have population densities at the present time which are lower than those of lowland portions of Pierce and Snohomish, but are significant nevertheless. The density of population growth in Kitsap and Island is expected to be comparable to that of Pierce and Snohomish. The highest density of manufacturing employment is in King County, largely due to the aircraft industry located there. Although Pierce and Snohomish have a lower density of manufacturing employment, the types of industries located within these two counties have a significant air pollution potential. Island County is primarily residential and recreational, with limited possibilities for major industrial development. Kitsap County is also primarily residential and recreational except for industrial activities associated with the shipyard. Under provisions in the Washington State Clean Air Act, all of the counties in the Puget Sound area except for Kitsap have activated their air pollution control authority and joined one of three multi-county agencies. The agency which has jurisdiction over the most highly urbanized area is the Puget Sound Air Pollution Control Agency. Its area encompasses three counties at the present time; King, Pierce, and Snohomish. Island County has joined San Juan, Skagit, and Whatcom to form the Northwest Air Pollution Control Agency. Six counties to the west of the Sound have joined to form the Olympic Air Pollution Control Agency. The thirteen counties included in these multi-county agencies and Kitsap County have been designated as an air pollution control district by recent amendments to the Washington State Statutes. The Puget Sound Governmental Conference, which handles a number of regional planning functions in the Puget Sound area,

covers a four-county area; King, Pierce, Snohomish, and Kitsap. On the basis of these findings, it appears that the present proposal for a Puget Sound Air Quality Control Region, to be designated in accordance with Federal statutes, should include at least three counties; King, Pierce, and Snohomish. Two other counties, Island and Kitsap, are candidates for inclusion due to their population densities, likelihood to experience significant population growth, and proximity to the Seattle urbanized area. However, since Island County has chosen to join with San Juan, Skagit, and Whatcom Counties, in accordance with State law, for the purpose of controlling air pollution on a multi-county basis, it would be undesirable to disrupt this existing multi-county relationship. Although Kitsap has not yet joined any multi-county air pollution control agency, it has established its membership within the Puget Sound Governmental Conference in order to coordinate its activities with King, Pierce, and Snohomish Counties on other regional problems. Therefore, it would seem natural for Kitsap to expand its relationship with the other three counties to include air pollution control activities.

# EVALUATION OF ENGINEERING FACTORS

## INTRODUCTION

A study of the technical aspects of air pollution in the Puget Sound area was based on consideration of pollutant emissions, topography, meteorology, and available ambient air quality data.

## EMISSIONS INVENTORY

An emissions inventory is a quantitative description of emission sources broken down by geographic location and each type of pollutant. The inventory usually identifies the "core" of an air quality control region -- that is, the area where the bulk of the emissions occur and throughout which control activities must take place in order to deal with a regional air pollution problem. For this reason, a presentation of the emissions inventory serves as a logical starting point in the engineering evaluation.

The National Air Pollution Control Administration conducted an inventory of air pollutant emissions for the Puget Sound area. The inventory was based on estimated rather than measured emissions. Emissions from about fifty major point sources (sources emitting more than 100 tons per year of any pollutant) were specifically listed in the inventory. Three major pollutants -- sulfur oxides, particulates, and carbon monoxide -- were considered in this study since emissions of these pollutants provide a general measure of the location and density of air pollution sources in the Puget Sound area. The emissions inventory emcompasses most of ten counties; Whatcom, Skagit, Snohomish, King, Pierce, Thurston, Mason, Kitsap,

Jefferson, and Clallam. This area was divided into the grid coordinate system shown in Figure 7. The estimated emissions of each of the three pollutants were expressed by grid zone as average daily emissions on the basis of an annual averaging time. Table I shows the annual-average daily emissions.

Emissions densities for each of the three pollutants, expressed in tons per square mile per day, were determined by relating the total emissions in each of the grid zones to the land area of that zone. Figures 8, 9, and 10 show the resulting densities on maps. Where point sources are responsible for more than 50% of the emissions in a grid zone, this fact is indicated in both Table I and the figures.

In general, the emission inventory maps indicate high emission rates in the central urban areas and along the corridor connecting Seattle, Tacoma, and Everett. Thus, the core area of emission sources appears to be contained by King, Pierce, and Snohomish Counties. In addition, moderately dense carbon monoxide emissions occur in Kitsap and Thurston Counties. Also, a few major point sources more than 40 miles away from downtown Seattle are responsible for significant emissions of sulfur oxides in Clallam, Skagit, and Whatcom Counties. Figure 11 shows the relative contribution of the various counties and various source categories to the total emissions of each pollutant. King, Pierce, and Snohomish are the three largest contributors to both particulate and carbon monoxide emissions. Pierce and Skagit are the largest contributors to sulfur oxides emissions. Among the source categories, road vehicles are responsible for about 95% of carbon monoxide emissions, industrial process losses for about 82% of sulfur oxide emissions, and

Figure 7:

EMISSIONS INVENTORY GRID SYSTEM

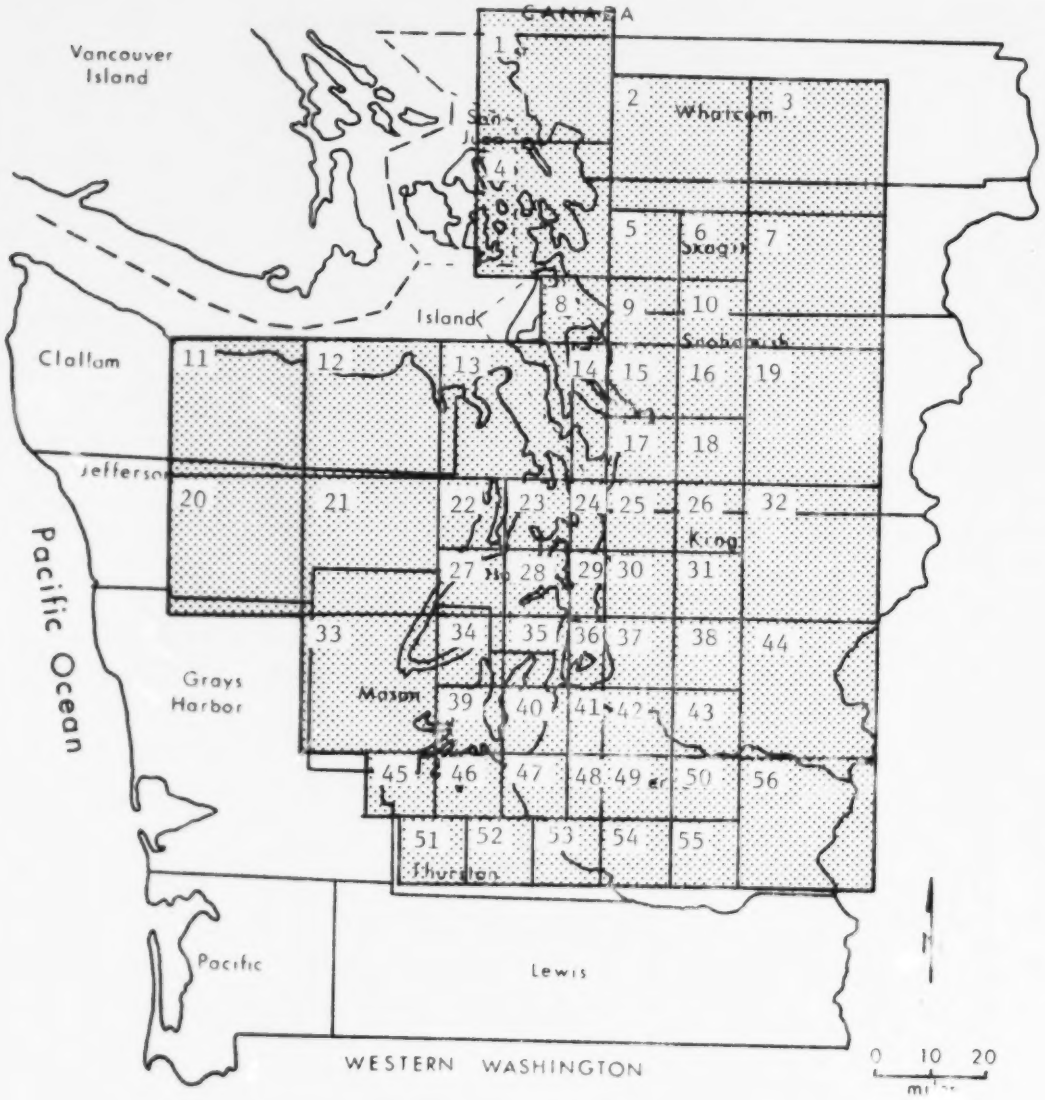


Table I

SEATTLE EMISSIONS INVENTORY

Tons Per Day

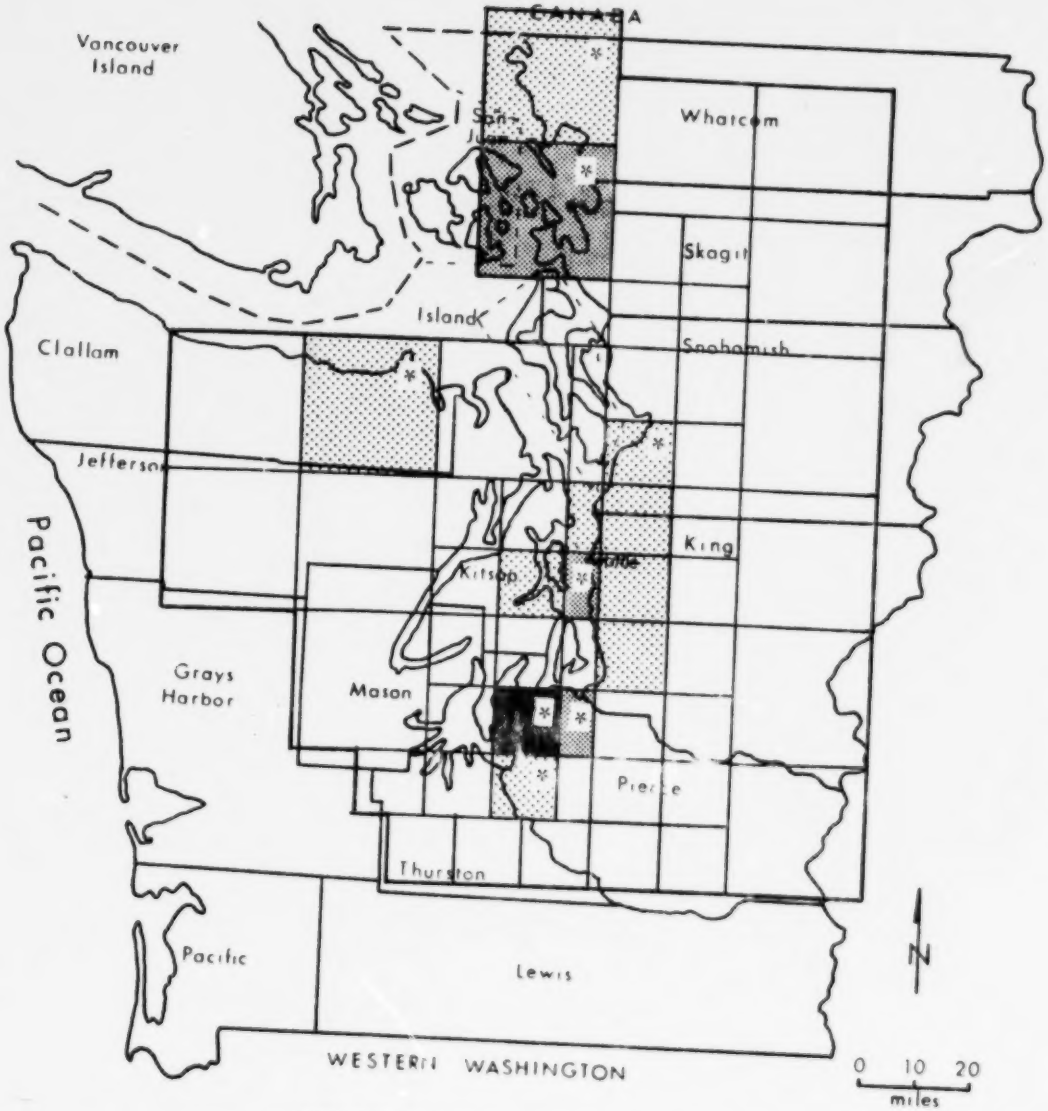
| Grid Number | Sulfur Oxide Emissions | Particulate Emissions | Carbon Monoxide Emissions |
|---|---|---|---|
| 1 | 45.50* | 3.57* | .87 |
| 2 | .06 | .03 | .09 |
| 3 | .05 | .04 | 2.03 |
| 4 | 76.00* | 2.92* | 33.25 |
| 5 | .33 | .29 | 8.77 |
| 6 | .12 | .12 | 8.03 |
| 7 | .08 | .07 | 5.07 |
| 8 | .06 | .21 | 13.37 |
| 9 | .05 | .16 | 10.03 |
| 10 | .09 | .09 | 5.65 |
| 11 | .07 | .06 | 4.25 |
| 12 | 19.30* | 2.44* | 35.55 |
| 13 | 4.50* | 3.95* | 12.89 |
| 14 | .00 | .00 | .00 |
| 15 | .11 | .31 | 20.89 |
| 16 | .03 | .07 | 5.35 |
| 17 | 10.10* | 7.68* | 62.94 |
| 18 | .26* | .40 | 15.50 |
| 19 | .11 | .11 | 7.19 |
| 20 | .00 | .00 | .05 |
| 21 | .01 | .01 | 1.15 |
| 22 | .01 | .02 | 2.28 |
| 23 | .31 | .19 | 11.80 |
| 24 | 4.14 | 2.61 | 148.99 |
| 25 | 3.28 | 3.58 | 245.28 |
| 26 | .03 | .09 | 6.33 |
| 27 | .05 | .03 | 1.82 |
| 28 | 1.74 | 1.29 | 50.42 |
| 29 | 14.96 | 11.65* | 251.38 |
| 30 | 11.15 | 10.35 | 329.77 |
| 31 | .13 | 1.36* | 21.07 |
| 32 | .09 | .11 | 9.85 |
| 33 | 1.11* | .40 | 20.35 |
| 34 | .04 | .05 | 3.41 |
| 35 | .22 | .39 | 17.61 |

* Indicates that more than 50% of the emissions in the grid zone are due to point sources.

| Grid Number | Sulfur Oxide Emissions | Particulate Emissions | Carbon Monoxide Emissions |
|---|---|---|---|
| 36 | .44 | .75 | 75.32 |
| 37 | 2.37 | 5.06 | 234.02 |
| 38 | .16 | .27 | 24.19 |
| 39 | .02 | .06 | 4.84 |
| 40 | 535.32* | 4.39 | 148.73 |
| 41 | 24.10* | 14.40* | 126.31 |
| 42 | .71 | 1.72 | 102.17 |
| 43 | .14 | .75* | 22.47 |
| 44 | .04 | .06 | 8.36 |
| 45 | .04 | .07 | 8.40 |
| 46 | .51 | 1.21 | 86.36 |
| 47 | 2.45* | 1.00 | 51.27 |
| 48 | .14 | .39 | 26.87 |
| 49 | .80* | .71* | 8.22 |
| 50 | .00 | .01 | 1.20 |
| 51 | .03 | .07 | 6.06 |
| 52 | .04 | .08 | 7.50 |
| 53 | .03 | .07 | 6.10 |
| 54 | .04 | .05 | 3.05 |
| 55 | .03 | .01 | 1.59 |
| 56 | .01 | .01 | 1.78 |

* Indicates that more than 50% of the emissions in the grid zone are due to point sources.

Figure 8:



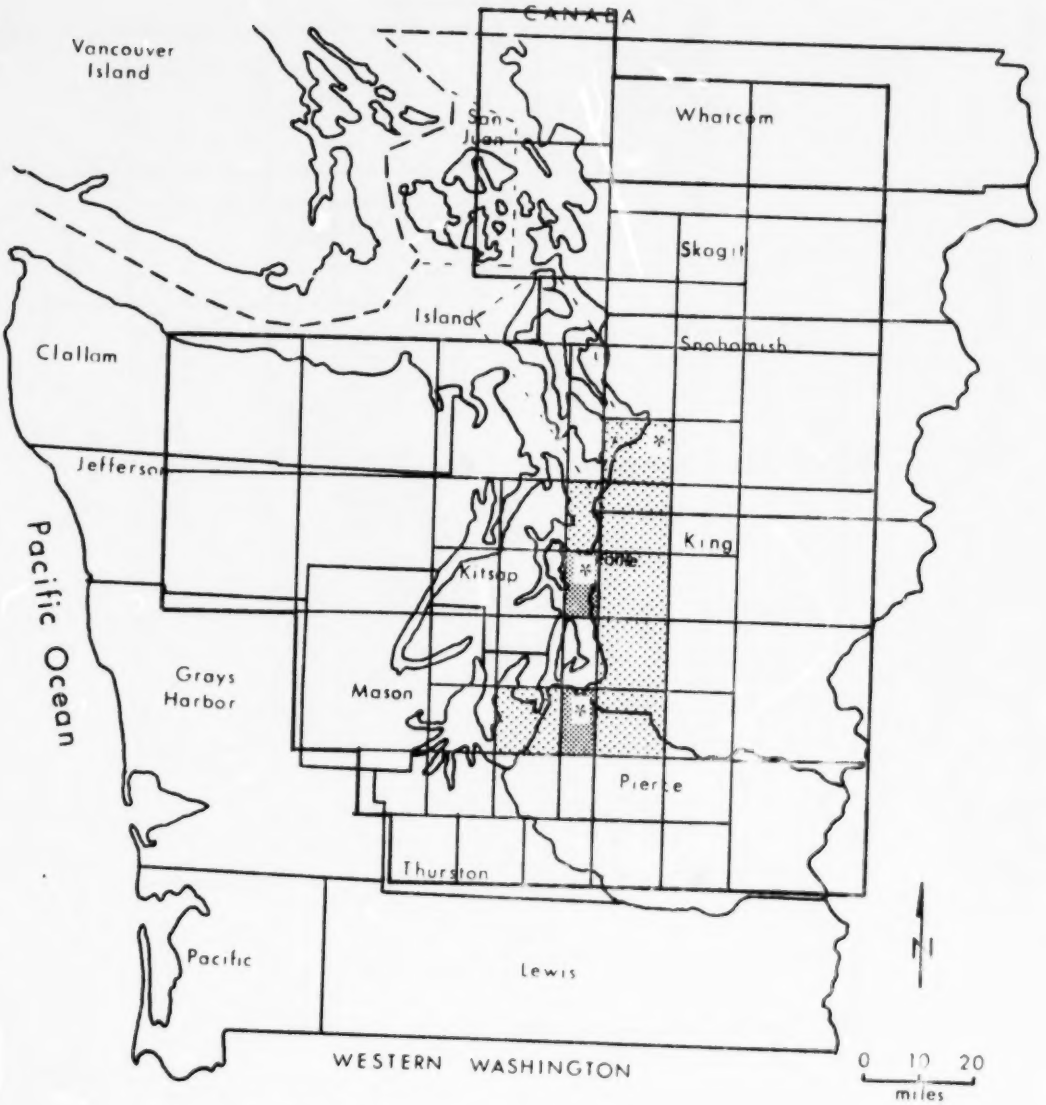

SULFUR OXIDES EMISSION DENSITY

Tons Per Square Mile Per Day

more than 1.0;
0.1 to 1.0;
0.01 to 0.1;
less than 0.01;

*indicates that more than 50% of the emissions in the grid are due to point sources.

Figure 9:



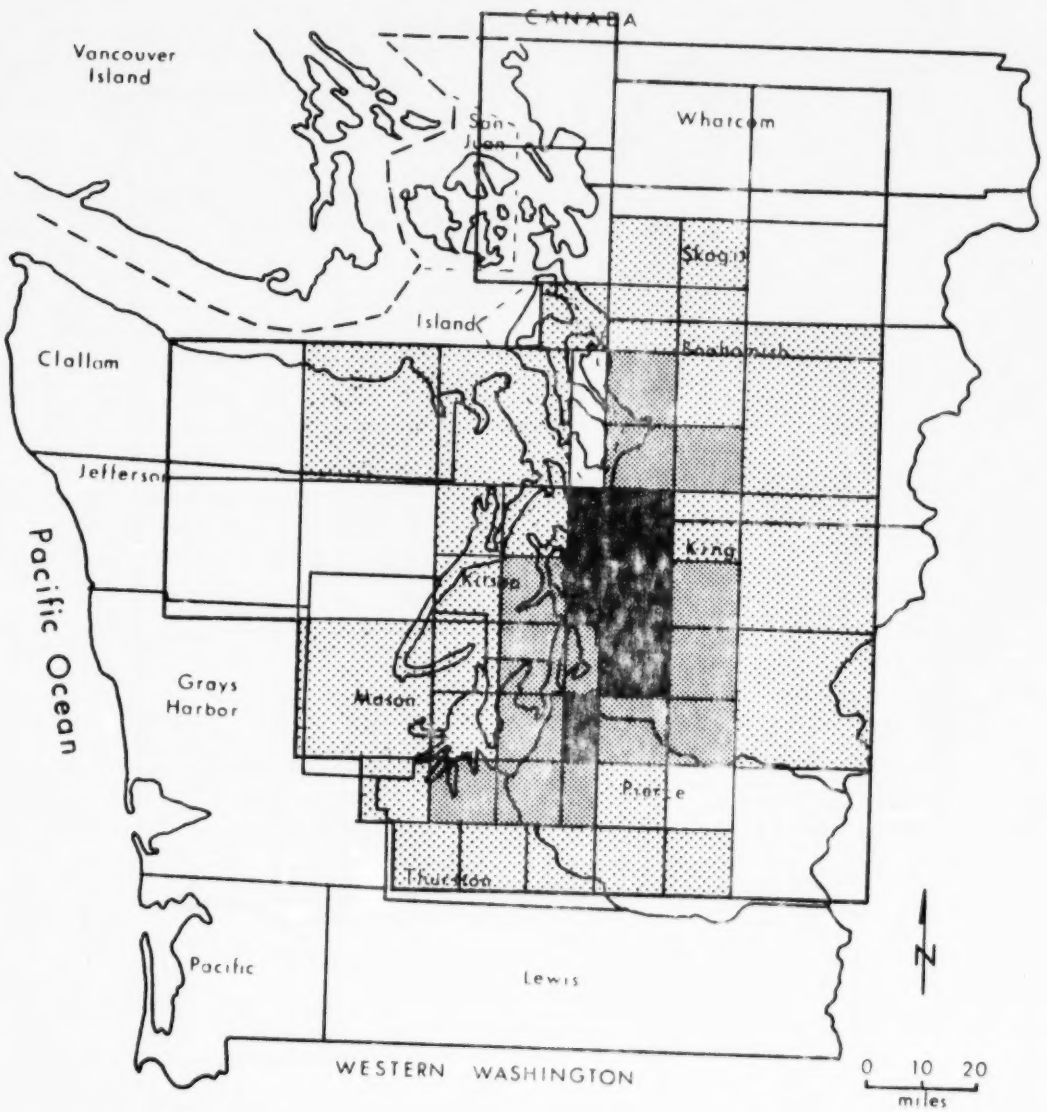

PARTICULATE EMISSION DENSITY

Tons Per Square Mile Per Day

- more than 1.0;
- 0.1 to 1.0;
- 0.01 to 0.1;
- less than 0.01;

*indicates that more than 50% of the emissions in the grid are due to point sources.

Figure 10:




CARBON MONOXIDE EMISSIONS DENSITY

Tons Per Square Mile Per Day

- more than 1.0;
- 0.1 to 1.0;
- 0.01 to 0.1;
- less than 0.01;

Figure 11:

PERCENTAGE CONTRIBUTION TO TOTAL EMISSIONS

A. By County

| Sulfur Oxides Emissions | | Particulate Emissions | | Carbon Monoxide Emissions | |
|---|---|---|---|---|---|
| Pierce | 74% | King | 42% | King | 59% |
| Skagit | 10 | Pierce | 26 | Pierce | 20 |
| Whatcom | 5 | Snohomish | 10 | Snohomish | 5 |
| King | 4 | Whatcom | 4 | Thurston | 4 |
| Clallam | 2 | Skagit | 4 | Kitsap | 3 |
| other | 5 | other | 14 | other | 9 |

B. By Source Category

| Sulfur Oxides Emissions | | Particulate Emissions | | Carbon Monoxide Emissions | |
|---|---|---|---|---|---|
| Industrial Process Losses | 82% | Industrial Process Losses | 28% | Road Vehicles | 95% |
| Industrial Fuel Use | 12 | Road Vehicles | 24 | Refuse Disposal | 4 |
| Other | 6 | Refuse Disposal | 18 | Other | 1 |
| | | Industrial Fuel Use | 17 | | |
| | | Other | 13 | | |

industrial process losses, road vehicles, refuse desposal, and industrial fuel use for the bulk of particulate emissions.

## TOPOGRAPHY

The emissions inventory identified the location of air pollution sources in the Puget Sound area. This section on topography and the following section on meteorology will consider the possibility of transport of pollution from the source locations to neighboring areas.

The Puget Sound forms a basin oriented in a north-south direction and bordered on the east by the Cascade Mountain Range and on the west by the Olympic Mountains. Both of these mountain ranges rise to elevations well over 5,000 feet. Figure 12 indicates those portions of the basin which lie below 2,000 feet elevation. These topographic features are the dominating influence on meteorology and air movement in the Puget Sound area, and therefore on the transport of air pollutants.

## METEOROLOGY

For previous urban areas subject to designation as air quality control regions, a diffusion model has been generally employed to establish the long term concentrations of pollutants transported in the ambient air. The reliability of this model is questionable in areas which have an uneven terrain or encompass large bodies of water. Since the Puget Sound is itself a large body of water and since it is bordered on two sides by mountainous areas, this section analysing pollutant transport will depend upon descriptions of air flow patterns, mixing depths, and dilution potential

rather than upon an application of the diffusion model.

Air Flow Patterns

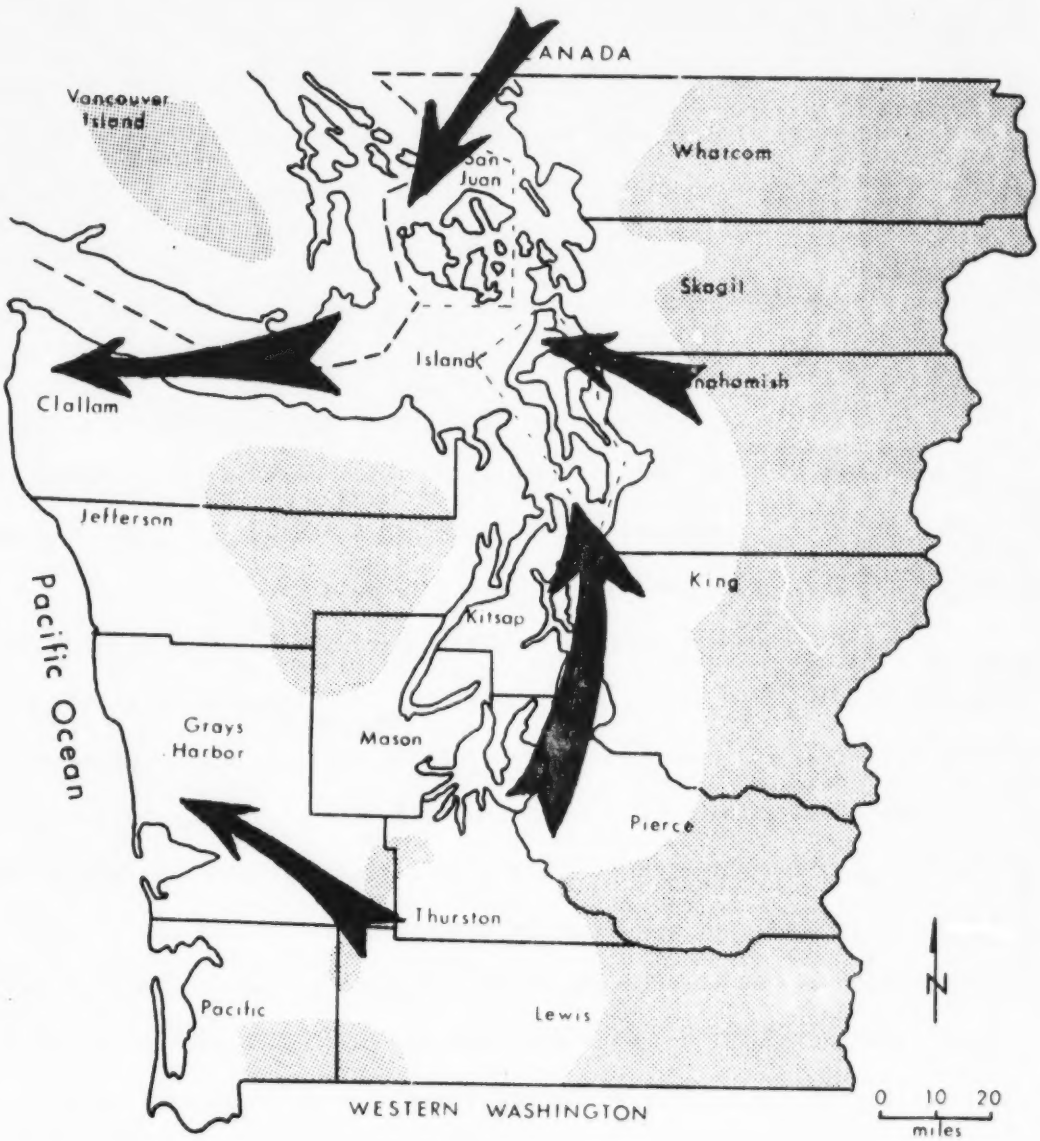
Air flow patterns are indicators of the manner in which pollutants are transported from sources to receptors. If a pattern shows that winds are generally weak or that there is no marked movement in one direction for a prolonged period, pollutants can be expected to stay relatively close to the sources. When winds persist in one direction for a long period, pollutants can be carried downwind long distances. The primary concern of this analysis is to determine the location of the outermost area affected by pollution from the metropolitan area. Major emphsis is on (1) persistent flows which would carry pollutants long distances and (2) light and variable winds which allow pollution to spread out radially.

The air flow over northwestern Washington has been documented in a number of summaries (7, 9, 11, 12, 15, 19, 20). The most detailed of these summaries (11, 15) are the major sources of the data presented here.

The winds within the Puget Sound basin are very strongly influenced by the topography and the north-south orientation of the basin. Winds blow primarily from either the north or the south, and follow the general orientation of the surrounding mountains. During storm periods, winds blow from the south, and when high pressure systems approach the area, the winds are usually northerly. During times of weak pressure gradients, local winds, such as sea breezes and air drainages from higher elevations, tend to dominate the circulation pattern. Figures 12-15 show the general flow patterns in the Puget Sound area based on the prevailing winds at various

Figure 12:

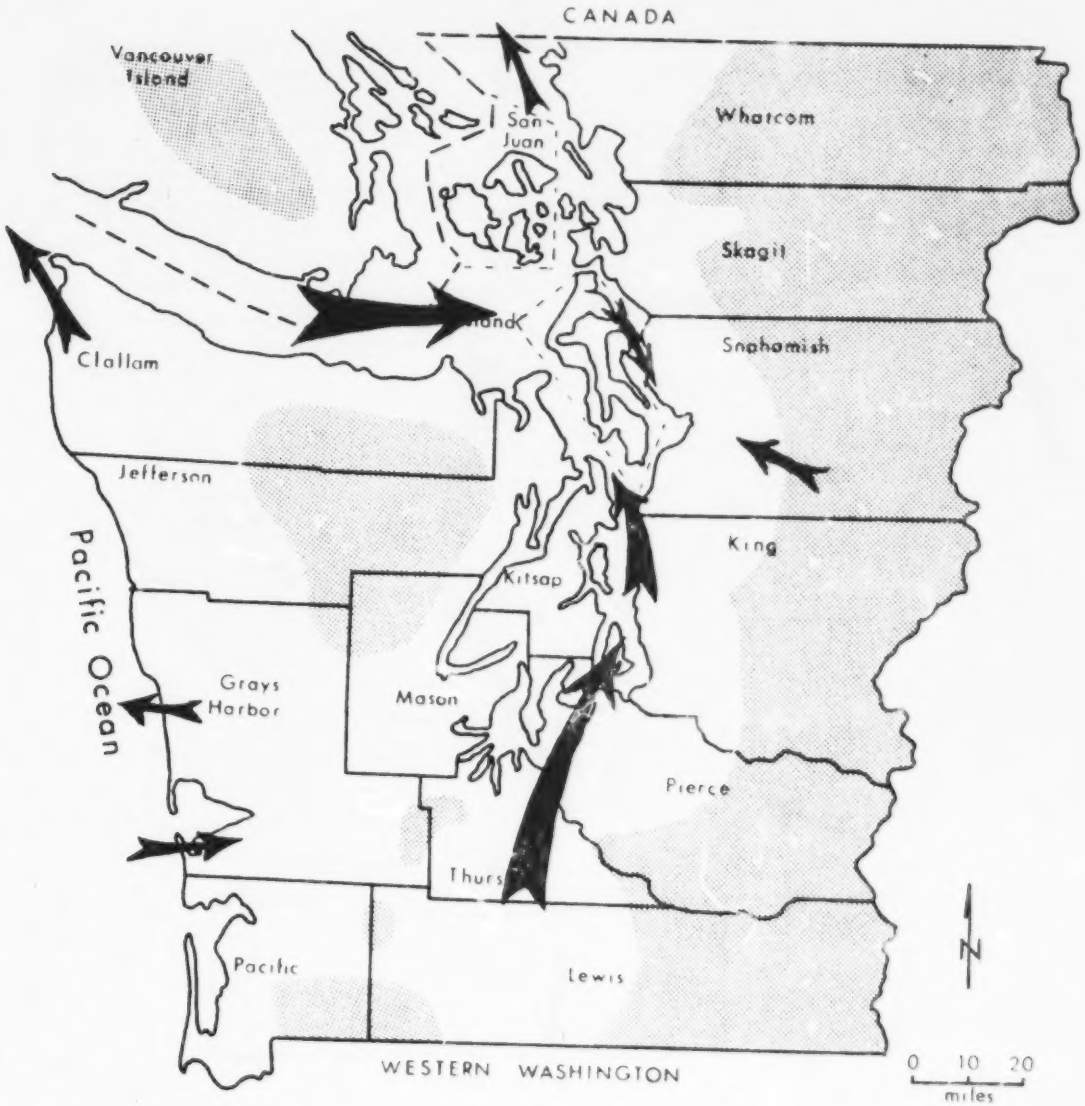
PREVAILING WIND DIRECTION; JANUARY




Areas over 2,000 feet elevation.

Figure 13:

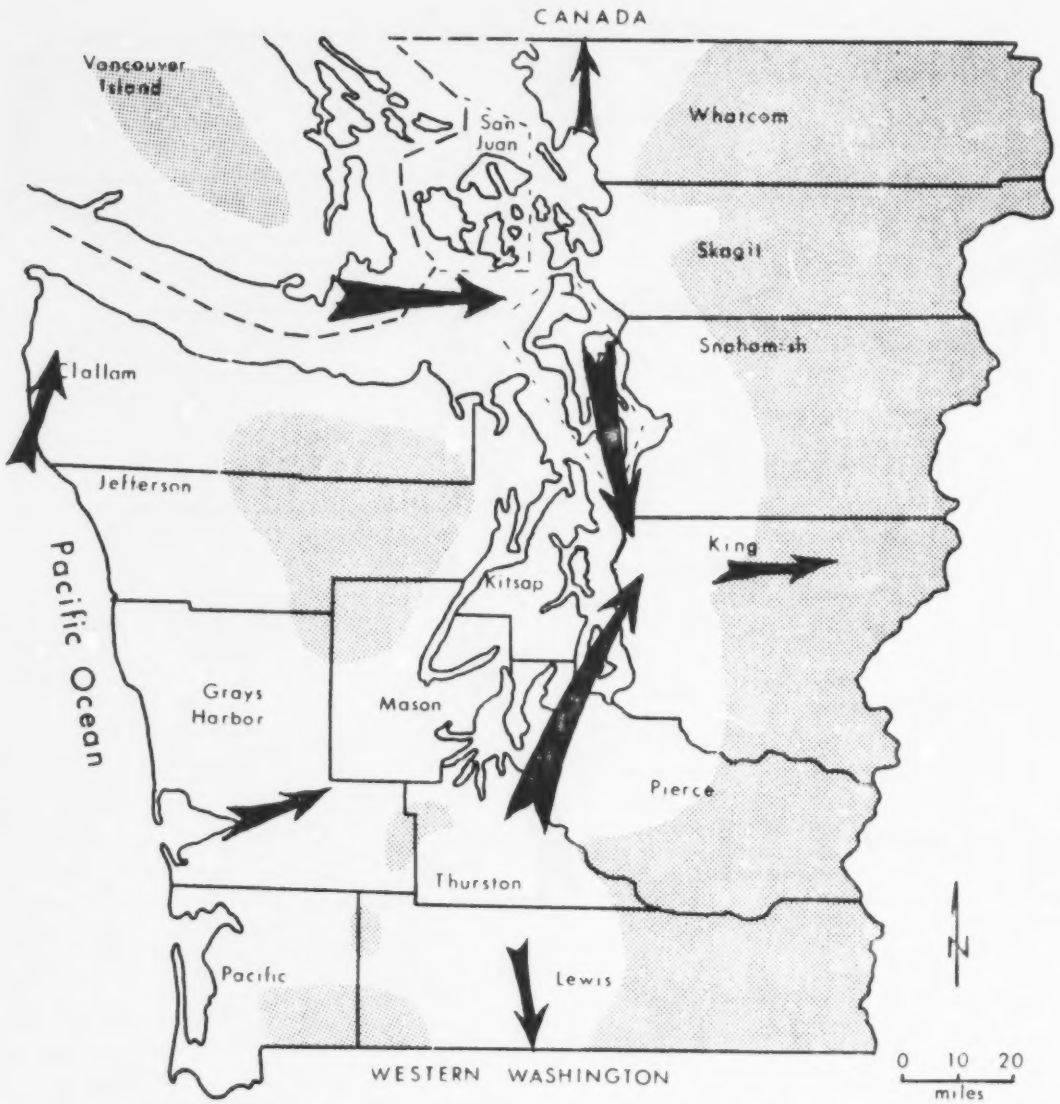
PREVAILING WIND DIRECTION; APRIL




Areas over 2,000 feet elevation.

Figure 14:

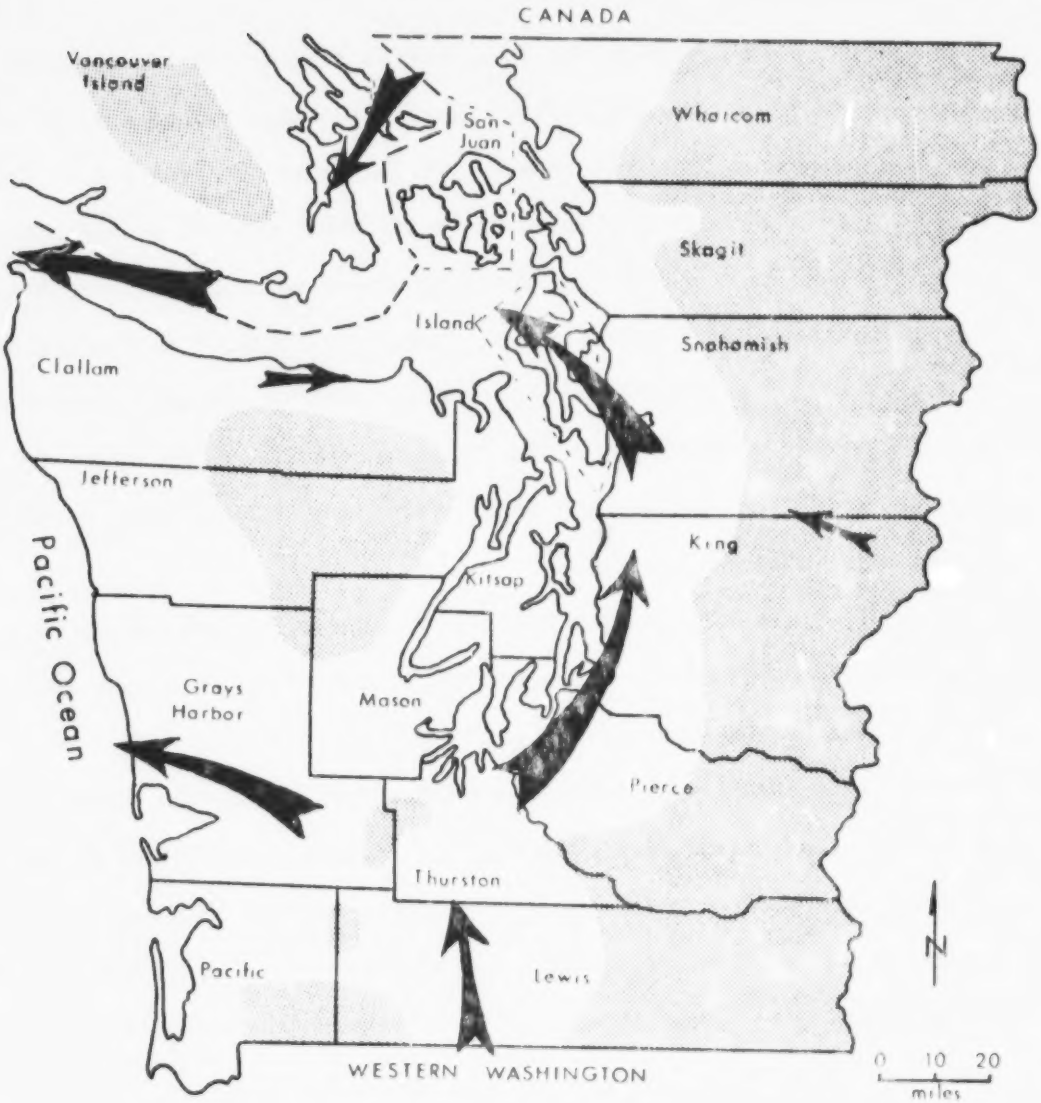
PREVAILING WIND DIRECTION: JULY




Areas over 2,000 feet elevation.

Figure 15:

PREVAILING WIND DIRECTION: OCTOBER




Areas over 2,000 feet elevation.

locations for the months of January, April, July, and October. The data used were wind speed and direction for all hours of the day for a five to ten year period.

The prevailing circulation in winter is illustrated by the January winds in Figure 12. The winds blow counter-clockwise around and toward the semi-permanent low pressure area off the coast creating a flow from south to north through the basin. There are brief periods of northerly winds after the passage of storms and when high pressure moves into the area. Wind speeds are fairly strong during winter, averaging 7 to 8 miles per hour. Periods of negligible or little flow (that is, calms) occur only 6 to 10 percent of the time in the northern portions of the basin and slightly more frequently in the south. Calms are somewhat more frequent during night than daytime.

During the spring months, there is a transition from the winter storminess to the summer dry season. The early spring winds are predominantly from the south. By April, Figure 13, a diurnal variation in wind direction becomes apparent at most locations along the Sound. The nighttime winds become almost exclusively southerly, while during the afternoon and early evening there is a marked tendency for westerly or northerly winds. At night, calms occur approximately 25% of the time at the southern end of Puget Sound and 10% at the northern end. During the day calms are infrequent.

In the summer months, air flows into the Puget Sound area from the ocean, passing through the Straits of Juan de Fuca into the northern portion and over the Grays Harbor area into the southern portion. This

creates a general flow from the north along the coast of Snohomish County and northern portions of King County, while southwest winds prevail over the southern Puget Sound area, Figure 14. There is a diurnal variation in wind direction at all locations along the Sound. From Seattle southward, daytime winds show a definite northerly component while nighttime winds are almost exclusively southerly. North of Seattle, the winds are predominantly northerly both day and night, but exhibit a westerly component during the daytime. Calms occur slightly more frequently during summer nights than spring nights, but occur rarely during summer days.

Fall is another transition period. September conditions closely resemble the summer circulation while November approximates the winter situation. The diurnal variation of the winds continues through September. During the day, northerly winds prevail at all locations from Everett to Olympia. During the night, the winds are southerly from Seattle southward, but remain northerly at other locations. An increase in the percentage of southerly winds occurs at all locations in October, Figure 15, and there is less evidence of reversing directions. By November, winds are primarily southerly. Calms in October are infrequent in the daytime, and at night occur 25% or more of the time at the southern end and 10 to 15 percent at the northern end.

## Mixing Depths

The calculated mixing depths for Seattle (14) are shown in Table II.

Table II

Average Mixing Depths, Meters:

Seattle, Washington, 1959-1961

| | Winter | Spring | Summer | Autumn | Annual |
|---|---|---|---|---|---|
| Morning | 626 | 681 | 532 | 476 | 679 |
| Afternoon | 580 | 1490 | 1398 | 898 | 1092 |
| Average | 603 | 1086 | 965 | 687 | 835 |

(100 meters = 328 feet)

These values, particularly in the fall and winter, are lower than the national average (13, 16) and indicate there is restricted vertical mixing and a limited volume of air available for dilution compared to many section of the nation. However, several investigators (7, 9, 10, 11) have reported that during the warm half of the year a subsidence inversion or stable layer with a base a little below 900 meters commonly occurs. These observations would indicate that the vertical mixing depths in the afternoon of late spring and summer are less than those shown in the table.

Diffusion Potential

When light winds occur from variable directions, pollutants tend to remain within relatively short distances of the source and to accumulate. Periods of light and variable winds are frequently accompanied by very limited vertical mixing depths. In western Washington, these conditions occur most frequently in the warmer months, April through October. Periods

with limited vertical mixing and light winds occur during the winter months on an average of only six days each month and seldom persist longer than 24 to 36 hours. Limited vertical mixing may also occur during the winter in conjunction with winds of stronger speed and more persistent direction. Under these circumstances, pollutants could be expected to travel greater distances while maintaining fairly high concentrations. The diurnal variation of both speed and direction during the warmer months indicates that pollutants generated within the Puget Sound basin area would tend to remain close to the major source areas unless dispersed vertically. The high frequency of low-level stable conditions during the warmer months leads to the conclusion that pollutants would accumulate during the nighttime near the source, travel only short distances during the day, and disperse vertically only when sufficient daytime heating occurs. The mixing depth figures in Table II and the findings of several investigators (7, 9, 10, 11) indicate that there is sufficient heating during spring and summer to allow vertical dispersion through approximately 3,000 feet during the day a large percentage of the time. Drainage winds at night and sea breezes in the daytime tend to reduce mixing depths and probably cause mixing depths less than the averages shown in Table II. The wind statistics indicate that these local winds may occur at least a third of the days.

When there are converging flows from the opposite ends of the Sound, the opposing flows do not move toward each other indefinitely. As they converge either they form a horizontal eddy or some air moves aloft or a combination of the two phenomena takes place. In any case, rather than

move out of the Puget Sound area, the air tends to remain within the basin. The limited vertical mixing prevents the low-level air from escaping into the winds aloft. Thus, any pollution within either of the converging flows would tend to stay in the basin.

## SUMMARY

The low area between the Olympic and Cascade mountains forms a basin within which pollutants tend to accumulate. Since the wind flow pattern is oriented along the north-south axis of the basin, transport of pollutants tends to be oriented in a north-south direction also. Thus, pollutants emitted along the urbanized corridor connecting Seattle, Tacoma, and Everett are more likely to move along the corridor than to spread westward across the Sound into Kitsap and Mason Counties. However, during periods of light and variable winds, accompanied by low mixing depths, pollutants are likely to spread out radially from the dense emission areas along the corridor, and could affect areas on the western side of the Sound. Portions of at least seven counties share a common air basin; Kitsap, King, Mason, Thurston, Pierce, Snohomish, and Island. Therefore, all of these counties could be affected to some degree by pollutants transported in the ambient air of the basin. Undoubtedly, the counties most affected are those which contain the most dense concentration of emission sources; King, Pierce, and Snohomish.

## MEASURED AIR QUALITY

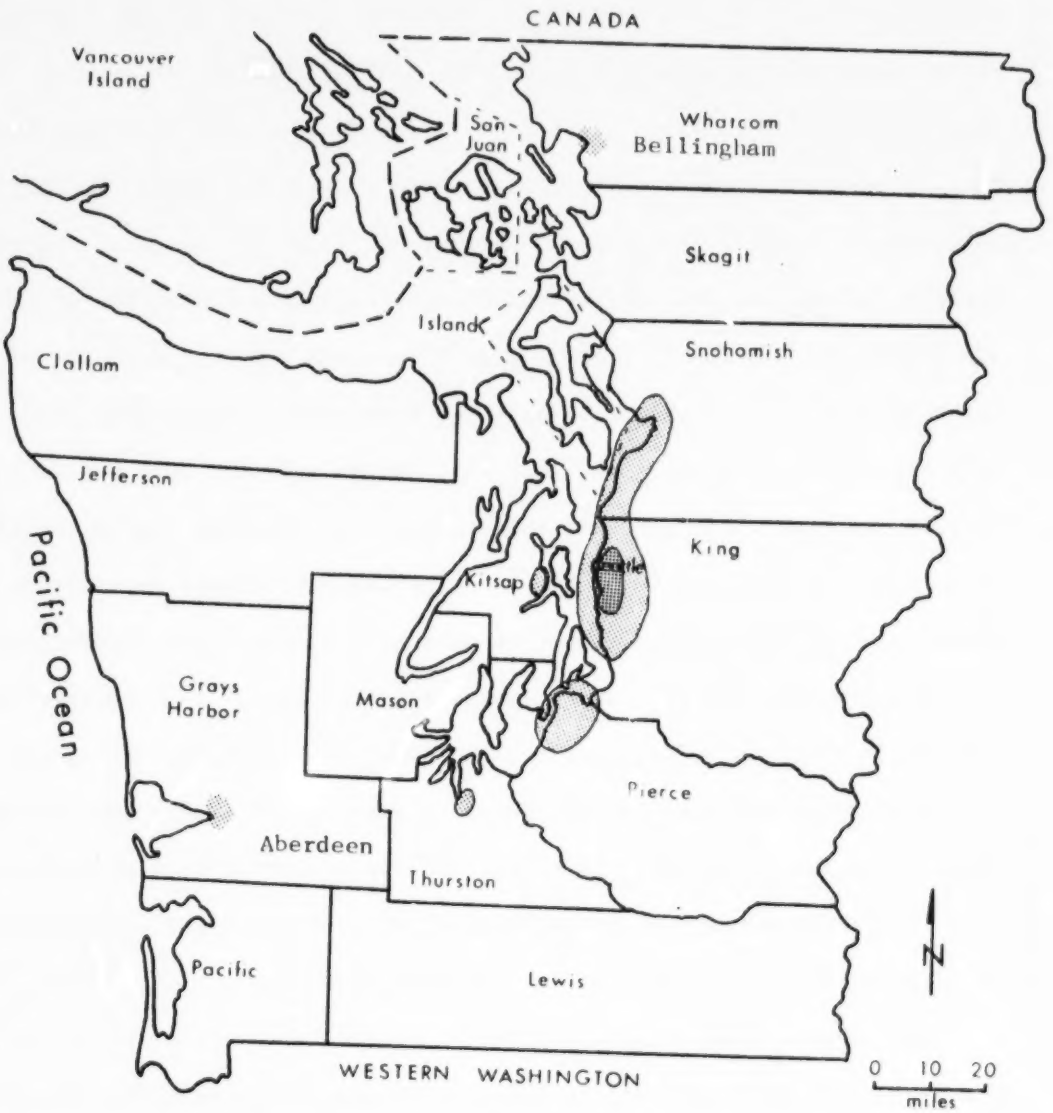
To the extent that reliable measured air quality data are available, they provide a direct indication of how large an area is affected by pollution sources in the Puget Sound area. Hi-vol samples for suspended particulates

have been taken at about twenty stations. However, about one half of these stations have collected data during only one year or less. Nine of the stations are located in King County, most of them within or near Seattle. Four stations are located in Pierce County, within or near Tacoma. Two stations are located in Snohomish, both in the vicintiy of Everett. Bellingham, Olympia, Aberdeen, Bremerton, and Mount Olympus each are the location of one station. Sulfur oxides have been measured at two stations, one in Seattle and one in Tacoma. Carbon monoxide has been measured at three stations, all in Seattle. Although lead candle measurements have been recorded at ten stations, they will not be reported here due to the lack of specificity in the pollutant measured by the lead candle technique.

Figure 16 portrays the measured suspended particulate data. Since the number of stations and the amount of data were limited, the concentrations contours shown in the figure are impressionistic rather than definitive. The contours indicate that particulate pollution is heaviest along the corridor from Everett to Tacoma. However, portions of Kitsap and Thurston Counties appear to be affected by particulate pollution to some degree. Particulate concentrations in Bellingham and Aberdeen constitute separate problems unrelated to the Seattle urbanized area.

The sulfur oxide levels recorded in Seattle and Tacoma are on the order of 0.03 parts per million based on an annual average. The data are insufficient to indicate how far sulfur oxide concentrations extend into surrounding areas. Carbon monoxide concentrations measured in Seattle range from about 2.0 to 5.0 parts per million on an annual average. Again, the data are insufficient to indicate how far carbon monoxide

Figure 16:




MEASURED SUSPENDED PARTICULATE CONCENTRATIONS

Micrograms Per Cubic Meter, Annual Average;

more than 100;
50 to 100;
less than 50;

concentrations extend into surrounding areas.

## SUMMARY

On the basis of topography and meteorology, portions of at least eight counties can be properly called part of the Puget Sound basin. The emissions inventory demonstrates that the bulk of particulate, sulfur oxides, and carbon monoxide emissions sources are located along the corridor of land on the eastern shore of the Puget Sound between Everett and Tacoma. The meteorological evaluation indicates that pollutants emitted along the corridor are generally transported along a north-south direction by prevailing wind patterns. Thus, pollutants emitted along the corridor are more likely to move along the corridor than to spread westward across the Sound. However, when winds are light and variable and when mixing depths are low, pollutants tend to accumulate near the source location and slowly spread out in a radial pattern. Although it is possible that all eight counties which share the Puget Sound basin are affected to some degree by transport of pollutants from the urbanized corridor, those counties most directly affected are King, Pierce, and Snohomish. Measured air quality data for suspended particulates confirm these conclusions. Iso-concentration contours are elongated in a north-south direction, and the highest concentrations of particulates are located in King, Pierce, and Snohomish Counties. On the basis of the engineering evaluation, three counties, King, Pierce, and Snohomish, constitute the minimum amount of area an air quality control region should contain in order to encompass the bulk of the sources and receptors. Kitsap, Thurston,

and Island Counties are associated with the regional air pollution problem to some degree, primarily as receptor locations. Jefferson, Mason, Skagit, San Juan, and other counties in the Puget Sound area are probably independent of the regional air pollution centered on the Seattle urbanized area.

# THE PROPOSED REGION

## PROPOSAL

Subject to the scheduled consultation, the Secretary, Department of Health, Education and Welfare, proposes to designate an air quality control region for the Puget Sound area, consisting of the territory encompasses by the following counties in the State of Washington:

King County

Pierce County

Snohomish County.

The boundaries of the proposed region are illustrated in Figure 17.

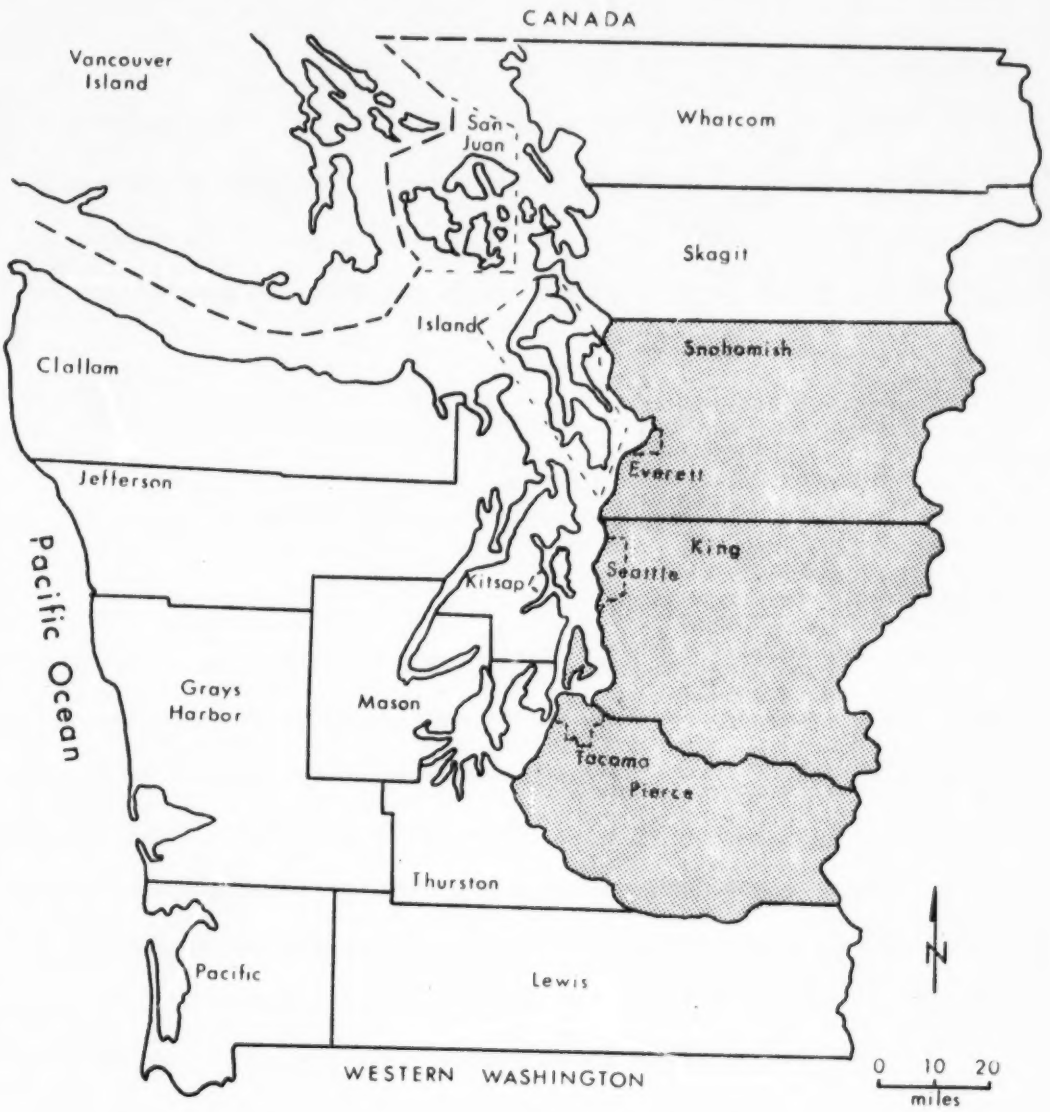
## DISCUSSION OF THE PROPOSAL

To be successful, an air quality control region should meet three basic objectives, as discussed in the section entitled "the size of a region", page 6. First, a region should be self-contained with respect to air pollution sources and receptors. Second, a region should be designed to meet not only present conditions but also future conditions. Third, region boundaries should foster unified and cooperative governmental administration of the air resource throughout the region.

The engineering and urban factors evaluations have shown that the most dense concentrations of air pollution sources and receptors are located along the corridor of land containing Everett, Seattle, and Tacoma. Approximately 80% of the total population of all counties which are adjacent to the Puget Sound lives in this corridor. Approximately 78% of the

Figure 17:

PROPOSED PUGET SOUND AIR QUALITY CONTROL REGION



particulate, 80% of the sulfur oxides, and 84% of the carbon monoxide emissions recorded in the emissions inventory occur within this corridor. Thus, the three counties which contain this corridor, King, Pierce, and Snohomish, constitute the basic core of the regional air pollution problem.

Mason and Jefferson Counties have very low population densities and growth expectations. Air pollutant emissions in these two counties are not significant enough to warrant inclusion in the proposed Region.

Although Thurston and Island Counties have greater population densities than Mason and Jefferson, they do not approach the density of development found along the eastern side of the Puget Sound between Everett and Tacoma. Neither of these counties contains industrial development large enough to constitute a significant source of emissions. Island County is expected to experience rapid population growth during the next sixteen years, but this growth is likely to be residential rather than industrial. Both Thurston and Island Counties have joined multi-county air pollution control agencies which do not have jurisdiction over the urbanized core of the Puget Sound basin. Neither Thurston nor Island has considered its future development as linked to the urban core closely enough to warrant membership in the Puget Sound Governmental Conference. On the basis of these considerations, Thurston and Island Counties have not been included in the proposed Region.

Kitsap County has a population density of 245 residents per square mile, which is more than twice as large as that of Snohomish County when computed

on a county-wide basis. As discussed in the urban factors evaluation, this comparison is misleading since most of the population in Snohomish County resides in the small portion of the county west of the Cascade Mountains. As a result, population concentrations in this section of Snohomish are much higher than what the county-wide statistics imply. Nevertheless, the above comparison does indicate that Kitsap has a sufficient population density to be a significant receptor location. Bremerton, the main urban center in Kitsap, is located only ten to fifteen miles from the heart of downtown Seattle. The meteorological evaluation indicates that under certain conditions pollutants generated along the eastern side of the Sound could be transported to the western side. Thus, Kitsap is occasionally affected as a receptor of regional air pollution in the Puget Sound basin. Except for naval facilities, Kitsap does not contain significant sources of pollutants. Although the Federal government retains jurisdiction over Federal facilities located in air quality control regions, control of emissions from those facilities is definitely influenced by local air quality and emission standards. Thus, it is possible that control of emissions from the naval facilities would be enhanced by inclusion of Kitsap in the Region. Kitsap is expected to register rapid population growth during the next sixteen years. This development is likely to be linked to increased urbanization along the eastern side of the Sound. In recognition of its present and probable future links with King, Pierce, and Snohomish Counties, Kitsap is participating in joint planning activities conducted by the Puget Sound Governmental Conference. All of the above considerations indicate that it

would be natural to include Kitsap County in the proposed Region.

However, since State and local governments have the ultimate responsibility for air pollution control in air quality control regions, and since Kitsap County has not yet chosen to join any of the multi-county air pollution control agencies in the Puget Sound area, the proposed Puget Sound Air Quality Control Region does not include Kitsap County. Positions expressed by State and local officials at the forthcoming consultation will be fully considered before any final designation is make either excluding or including Kitsap in the Region.

Region boundary designations are not intended to be inflexible if changing conditions warrant changes in boundaries. In this regard, if Kitsap County is not included in the Puget Sound Air Quality Control Region at this time, it should be the subject of frequent review and should be considered for inclusion in the Region at a later date if urban and industrial development in the future warrant such action.

This report and the Region boundaries which it proposes are a starting point for discussion in the consultation with appropriate State and local officials.

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